10/068023

SUBSTITUTE SPECIFICATION STATEMENT

To fulfill 37 CFR 1.125(b)

1) This substitute specification includes no new matter in terms of inventive material. It does include the updated and most accurate equations (as explained in the previous specification) and revised wording to provide a cleaner more succinct application.

2) Please see attached marked up version which is labeled as: "MARKED UP VERSION"

To fulfill 37 CFR 1.125(c)

I submit substitute specification in clean form and label paragraphs in Arabic numerals.

3) I cancel rejected claims 1, 2, and 3 and submit claims 4 and 5 for approval.

TITLE OF THE INVENTION

A ROOF VENT SYSTEM WHICH PREVENTS ROOF LOSS / LIFT OFF IN HIGH WINDS

Inventor: St.Jean Orridge

CROSS-REFERENCE TO RELATED APPLICATIONS

6,484,459 B1	11/2002	Platts
4,144,802	03/1979	Babin

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

INCORPORATION-BY-REFERENCE OF MATERIAL SUBMITTED ON A COMPACT DISC

Not Applicable

BACKGROUND OF THE INVENTION

paragraph1.

1. Field of the invention:

This invention relates to the effects of high winds (hurricanes and tornadoes) on the roof structures of buildings. It is an invention for a roof vent system, which prevents roof loss due to high wind events. It does this by limiting the pressure difference that can occur across the roof of the structure to a set value. The system is made of simple components, which are inexpensive and do not compromise the system's effectiveness as they age. As such it addresses in a cost effective and quantitative manner, the problem of roof loss that is associated with high-speed winds.

paragraph2.

2. Related art:

The related art (Babin, 4,144,802...03/1979 and Platts 6,484,459...11/2002) also deals with roof vent systems. One facet of Babin's system is that it uses vents to release, relieve or equalize the pressure differences that can develop across a roof during high wind events. The downfall of this system as I see it is that whilst equalization, relief or pressure release occur, the system does not prevent pressure differences from developing which might be sufficient to lift off the roof.

The Platts, system is designed to drop the pressure inside the building to help protect the roof, but it does not ensure that the interior pressure drops at a sufficient rate to prevent a pressure difference developing across the roof that is sufficient to lift off the roof. Again, it is not designed to absolutely limit the pressure difference that can occur.

DETAILED DESCRIPTION

SUMMARY

paragraph3.

This system works by limiting the pressure difference that may occur across a roof. Initially, a quantification of the greatest pressure drop that can possibly occur above a roof per unit time must be arrived at. (Data must be collected from hurricane and tornado events). Next the allowable pressure difference that may occur across the roof must be measured (the allowable pressure difference is less than the pressure difference required to lift off the roof). This allowable pressure difference acts as the maximum potential driving force for air evacuation from the interior of the building. It also dictates the parameters within which the building's internal pressure curve must follow the external curve. Finally the volume of the building must be measured. From this the mass of air that must be evacuated to keep the internal pressure curve within the set acceptable pressure difference from the external curve can be quantified. An equation which provides the area of open venting required to evacuate a given mass of gas has been written. Thus a solution for the minimum vent area required can be arrived at.

paragraph4.

In the simplest sense, a known force is expelling a known quantity (mass) of air from an enclosed space. It must be done within a set time limit. Thus the value of the minimum area of venting required to achieve this can be solved for.

DETAILED DESCRIPTION OF INVENTION

FORCES ACTING ON A ROOF

paragraph6.

As fast flowing air passes over a roof, there is a resulting lowering of pressure (Venturi effect and turbulence) See Fig 2 .Thus the pressure outside the building (above the roof) is lower than the pressure inside the building (below the roof). Pressure is a force/unit area. In order for the roof to lift off of a house, the forces acting upwards must be greater than the forces acting downwards See Fig 3.

In the simplest equation format, if

$$\left[\frac{\text{Weight of Roof}}{\text{Unit Area}} + \text{External Pressure} \geq \text{Internal Pressure}\right]$$

then a roof will always stay on. There is no net force upwards.

paragraph7.

It should be possible to quantify with a rough degree of accuracy, using a conservative value the minimum tensile strength of the connections linking the roof to the walls as well as the minimum tensile strength of the roof material itself. These factors can then be incorporated into the above equation to give a more accurate (although less conservative) value for the maximum allowable pressure difference.

$$\frac{\text{Weight of Roof}}{\text{Unit Area}} + \text{Tensile strength of connections} + \frac{\text{External Pressure}}{\text{Unit Area}} \geq \frac{\text{Internal Pressure}}{\text{Unit Area}}$$

$$\frac{\text{Weight of Roof}}{\text{Unit Area}} + \text{Tensile strength of connections} \geq \frac{\text{Internal Pressure - External Pressure}}{\text{Unit Area}}$$

paragraph8.

These equations illustrate that the air pressure difference between the interior and exterior of the building acting upwards must at all times be less than the weight/area of roof plus the factored effect of the tensile strength of connections and roofing material acting downwards.

paragraph9.

In order to allow air to flow across the roof and thus control this pressure difference vents are used.

PREFERRED VENT DESIGN

paragraph10.

Ideally one wants the vent design to be as streamlined as possible so that the air passing through the vent is traveling at the same speed and creating the same lift effect as the air flowing over the adjacent roof. Wind tunnel tests that quantify the friction of air flowing through the vents will allow if necessary a compensating adjustment of the calculated minimum venting area required. (This friction is that experienced by the air passing in under the vent cap and out the other side, not the air moving from the interior of the building through the vent to the exterior.)

paragraph11.

Vent design See figs 4a through 4f.

Vent Performance Points

1) Cap prevents rain from entering, (even most horizontally blown rain).
2) Cap is smaller than base plate so that bars slope in. This makes it more difficult for blown debris to catch on the vent.
3) Vertical bars are spaced such that the gap size doesn't allow bees access. (vents cannot become hive sites)
4) Any water that does enter the vent shaft is collected and channeled through a tube into the drains. The tube might alternatively direct the water outside the building, if this proves easier.
5) The central plug is 'free floating' on a central shaft. It is designed to be lifted by high speed winds and its weight / area is low enough to ensure that it will be lifted and the vent is open by the time that the maximum allowable pressure difference is reached.
6) Once the central plug is pushed up it acts like an airplane wing. Air rushing through the vent 'flies' the central plug up on its shaft. The vent stays open as long as high-speed winds are blowing through it. When the wind speed drops the plug sinks down to close the vent.
7) The central plug is built with a small single direction flow valved hole, the valve flow direction being from outside towards the inside of the building when said plug is closed (the purpose of this valve being to allow air to 'leak' back into the building when the vent is closed).

This preferred vent design will only be open in hurricane/tornado conditions. The rest of the time it will remain shut.

CONSIDERATIONS OTHER THAN VENTS

paragraph12.

1) Increasing the weight of the roof will make it more difficult to lift off (e.g. attach weights to rafters, or the plywood roof sheeting). The disadvantage to this however, is that in the event of a building collapsing during a storm, as materials such as wood or metal weaken with age, rust, termites or rot there is the potential for a lot of heavy weight landing on someone.

paragraph13.

i. Decreasing wind speed over the roof. (I am not convinced that it would be possible to effectively limit wind speed by creating a certain roof profile)
   See Fig 5

paragraph14.

ii. Increasing the tensile strength of roof connections and roofing materials. This should be somewhat effective however it does have drawbacks:
   a) It can be expensive to rebuild houses with higher quality and greater tensile strength materials. There is also decreasing reliability as metals oxidize and weaken, and wood tensile strength may deteriorate through dry rot or termite action. (Both these factors are difficult to quantify exactly so the real tensile strength may be tough to pinpoint)
   b) This approach does not act to remove/limit pressure stresses it 'fights' them. Thus whilst the edge of a roof may be secured, if there is a weak point of attachment in the center or any weak point anywhere the intense pressure differences are still there to exploit the weak link and thus roof loss may still occur

paragraph15.

Each methodology has its distinct advantages and drawbacks. I believe however that the cheapest, most durable and most comprehensively effective way to prevent a building from loosing its roof will prove to be the vent system approach. Putting in vents is extremely cheap. Vents are really just an open empty hole for air to flow through and this does not 'decay' over time. (Homeowners need only ensure that come hurricane/tornado season their vents are not plugged for any reason) Finally, vents offer a quantified approach which actually limits the forces at play across the roof. A quantifiable solution is something which is extremely desirable for problems of this nature.

THE USE OF VENTS, A CALCULATED NUMBER (SURFACE AREA OF OPEN VENTING) WITH RESPECT TO VOLUME OF BUILDING.

paragraph16.

In order to calculate the surface area of open venting (number of vents) that a given building requires to prevent roof loss the following series of steps must be taken.

i. The greatest pressure drop per unit time that can occur above a roof must be quantified.

ii. The pressure difference across the roof that is allowable for each type of roof construction must be measured (i.e. the pressure difference that a given type of roof will tolerate before it is blown off).

iii. Using the information from A and B the pressure change (drop) per unit time that must occur inside the building can be quantified and the venting area required to achieve this can be calculated.

A)

paragraph17.

A continuously recording pressure-sensing device must be set up on roofs in various high wind events (hurricane, tornado). This will provide data of actual worst case scenario pressure changes which must be dealt with above a roof. (This type of data may already have been generated and must simply be referenced).

The data generated may be in the form of a straight line graph (see fig. 8) as pressure changes between two time points or a curve. In the instance where it is a curve it is important to take the gradient of the steepest point of the curve (see fig. 9).

paragraph18.

If Equation C (which follows) is used with a curve such as that in fig 9 and the end points $t = 0$, $t = 3$, are used the predicted vent surface area required will correspond to the straight-line pressure change. $P*$ will go above its preset constraint and so will not truly represent a maximum allowable $P*$. To get a solution for vent surface area which maintains the maximum allowable $P*$ the point which is the steepest gradient of the curve must be taken. Using that gradient line, extrapolate to your time end points and use this as your worst case pressure change value to substitute into Equation C. The vent area calculated from this will be the minimum required to absolutely ensure that the $P*$ designated represents a maximum allowable $P*$ and stays within its set constraint.

paragraph19.

It is perhaps important to note that rating a building for a certain wind velocity is misleading as a rating standard. This rating is done in a wind tunnel where air speed is gradually increased to a certain value. This means that the pressure drop associated with high speed wind above the roof is also gradual. Any minute gaps in a model building's

joints, which are inevitable in any construction, will allow an opportunity for the relatively higher-pressure air inside the model to be drawn out. Thus as long as the air velocity increase above the roof is gradual, the roof may not lift off. A more accurate rating is only achieved when worst-case pressure drops per unit time are quantified (i.e. maximum wind accelerations and their maximum duration). If wind velocity is the only yardstick used one might find that a roof will withstand gradual wind speed increase up to 140mph, but a sharp gust between 40mph and 90mph is sufficient to lift off the same roof.

paragraph20.

From A) the maximum pressure change that can occur in the shortest period of time above a roof is known. Therefore one knows what pressure change must occur inside the building to prevent a pressure difference (P^*) between the inside and outside of the roof sufficient to lift the roof off.

B)

paragraph21.

The pressure difference between the inside and outside of the building must at all times be below a certain value. That value is the one at which point the roof will lift off. As explained earlier this value can be calculated very accurately using the weight of the roof/unit area, and a conservative value for the tensile strength of attachments to walls, wall weight etc. However, one could also just build in a safety margin and make the maximum allowable pressure difference the weight/area of the roof ($^4/_5$ weight/area or $^3/_4$ i.e., whatever safety margin one chooses to create).
I will show scenarios using the weight/area of the roof as the allowable pressure difference.

It should be noted that pressure acts perpendicularly to a given surface. See fig 6a

So in the case of a roof the pressure acts perpendicularly to the roof surface whereas weight acts directly downwards. See fig 6b

Thus more accurately the pressure difference (P^*) must be less than the weight/area (cosϑ) to prevent roof loss.

Pressure inside - Pressure outside = P^*
P^* must be less than roof weight/area (cosϑ).
$P^* <$ weight/area (cosϑ).

C)

Knowing the exterior pressure change (worst-case scenario data) one knows what the interior pressure must match to stay within the allowable P^*.

See Fig 7
The above graphically defines what the interior pressure curve must be to be useful (i.e., prevent roof loss). Now it is necessary to calculate the area of roof venting (number of vents) necessary to achieve this.

paragraph22.

The first step in this process is as follows:

1) Calculate the number of moles of gas (air) which must be removed from the interior of the building to keep the pressure difference within the allowable P^* at the point of lowest external pressure (max wind velocity). The interior of the building can be treated as a closed system, and the ideal gas equations can be applied.

Using the gas equation PV = nRT

P = pressure n = number of moles
V = volume R = gas constant T = temperature

I will be using the sign ↓ to indicate a known value
The initial interior pressure = initial exterior pressure.

The external maximum pressure change quantified in section A) does not have set starting and finishing values. The measured value represents only a maximum pressure change, which can be encountered. In a building with fixed volume, where R is a constant and T can be measured and set, it does not matter what starting point is taken. Whatever your starting pressure, if the maximum potential pressure change is subtracted from this, the number of moles to be evacuated is always the same. (Within the constraints of the ideal gas equations).

Volume of building is known
R is the gas constant
T (Temperature) can be set at a typical value for a high wind event in that region. (To be on the safe side, set the temperature at a lower value than it is ever likely to be. This will make the n (number of moles) to be evacuated larger than it will ever have to be, i.e. a built-in safety margin).

eP represents external pressure.
iP represents internal pressure.
P_f represents final pressure.
P_i represents initial pressure.
n_f is final number of moles.
n_i is initial number of moles.

Externally (above the roof),
$eP_f - eP_i$ = the worst case scenario pressure change as measured/taken from storm data.

Internally (within the building),
$iP_f - iP_i$ as an absolute value = absolute value of external $eP_f - eP_i$, subtract P^*.

These are known values.

(Equation A)→ $$\overbrace{\left|eP_f - eP_i\right|}^{\downarrow} - \overset{\downarrow}{P}{*} = \left|iP_f - iP_i\right|$$

$$iP_f \overset{\downarrow}{V} = n_f \overset{\downarrow}{R}\overset{\downarrow}{T}$$

$$iP_i \overset{\downarrow}{V} = n_i \overset{\downarrow}{R}\overset{\downarrow}{T}$$ subtract initial interior pressure from final interior pressure

$$(iP_f - iP_i)\overset{\downarrow}{V} = (n_f - n_i)\overset{\downarrow}{R}\overset{\downarrow}{T}$$

$$(iP_f - iP_i) = \frac{(n_f - n_i)\overset{\downarrow}{R}\overset{\downarrow}{T}}{\underset{\uparrow}{V}}$$

substitute from (equation I)

$$\overbrace{\left|eP_f - eP_i\right|}^{\downarrow} - \overset{\downarrow}{P}{*} = \frac{(n_f - n_i)\overset{\downarrow}{R}\overset{\downarrow}{T}}{\underset{\uparrow}{V}}$$

$$n_f - n_i = \frac{\left(\overbrace{\left|eP_f - eP_i\right|}^{\downarrow} - \overset{\downarrow}{P}{*}\right)\overset{\downarrow}{V}}{\underset{\uparrow}{R}\underset{\uparrow}{T}}$$ ←(Equation B)

Thus $n_f - n_i = n$ moles of gas which must be evacuated from the building to keep P^* within its set constraints.

This n moles of gas will have a certain mass (i.e., composition of air %N, 0_2, $C0_2$, etc.) which can be calculated.

paragraph23.

<u>Summary of what is known for any given building</u>
(i.e. what has been measured and what can be calculated)

1) The time over which the external (and therefore internal) pressure change occurs and the value of that change (from worst-case scenario data).
2) The number of moles which must be evacuated from the building.
3) The mass of gas which must be evacuated.
4) The P^* (this is measured and set for each given roof).

Now it is possible to write some further equations.

We know that the friction force on a body in fluid resistance as a body passes through a fluid or reciprocally the friction force on a fluid effected by a body as the fluid passes over that body may be written as $f = kv$ for low speeds and $f = kv^2$ for high speeds.

For a given vent in this system P^* is the maximum force that it will encounter and at terminal velocity $P^* = -kv_t^2$. Thus for the vents specified in this system wind tunnel tests where P^* is applied across the vent and v_t is measured will allow a value for k for this specific vent to be measured.

$P^* = -k\,v_t^2$ The k and v_t are known/measured values from the specified vent.

$P^* = \dfrac{m\,a}{area}$ m (mass) is known from the n (number of moles) previously calculated.

$$P^* = \frac{m\dfrac{dv}{dt}}{area}$$

$$\overbrace{\left(-kv^2\right)}^{\downarrow} = \frac{\overset{\downarrow}{m}\dfrac{dv}{dt}}{area}$$ This equation is true as long as the end points chosen for the integration with respect to v end with v at v_t. This makes sense as v must go to v_t for $P*$ to be reached, and any pressure difference less than $P*$ is no threat to the roof.

$$area = \frac{\overset{\downarrow}{m}}{\underbrace{\left(-kv^2\right)}_{\uparrow}}\frac{dv}{dt}$$

$$\int area(dt) = \int \frac{\overset{\downarrow}{m}}{\underbrace{\left(-kv^2\right)}_{\uparrow}}(dv)$$

$$\left[area(t)\right]_o^{\overset{\downarrow}{t}} = \left[\frac{\overset{\downarrow}{m}}{\underset{\uparrow}{k}}v^{-1}\right]_o^{v_t}$$ t is the time over which the worst case pressure drop occurs

$$area(\overset{\downarrow}{t}) = \frac{\overset{\downarrow}{m}}{\underset{\uparrow}{k}\,\underset{\uparrow}{v_t}}$$

(Equation C) $\rightarrow \left[area = \dfrac{\overset{\downarrow}{m}}{\underset{\uparrow}{k}\,\underset{\uparrow}{v_t}\,\underset{\uparrow}{t}}\right]$ where m is the mass calculated from n moles to be evacuated as taken from worst case pressure drop measurements. k and v_t are the values measured from wind tunnel tests performed on the specific vent type, and t is the time over which the worst case pressure drop occurs.

SOME POINTS FOR OVERALL SYSTEM SETUP

paragraph24.

In many buildings/houses there may be a space below the roof.
See Fig 10a

The vent system must be in place between space A&B space B&C and space C&D.

Between floors a stairway will probably be sufficient surface area (allow sufficient volume flow)

Rooms with doors that might potentially be closed must have vents. One would simply apply Equation C to calculate the surface area of venting necessary to evacuate each room's volume.

See fig 10b

See fig 10c

See fig 10d
The flow route may be designed as one wishes, but everything must flow out through the roof in this open, free-flowing vent system.

VENT PLACEMENT PARAMETERS

paragraph25.

The area calculated as being the minimum required to ensure that a roof does not blow off could be divided up into many vents, or it could be built as one giant vent. This system is designed to work when the whole roof (and thus the entire minimum required venting) is exposed to the high wind situation.

paragraph26.

PARAMETER 1

The scenario depicted below shows a situation that represents the system's first modification parameter.

The pressure decrease due to high winds only occurs where there is high-speed airflow. If wind speeds are high at A and very low at B, a vent where low wind speeds occur does not experience a pressure difference that would contribute to the evacuation of the building's air. There is also of course no lift force exerted on the roof at this point and thus no need to evacuate air to effect a limitation of pressure difference for that part of the roof. However, at point A where high-speed winds are blowing, the entire minimum venting area required would need to be present. (This assumes that it is possible to experience a worst-case scenario pressure drop at one end of the roof and no pressure change at the other.) In order to quantify the possibility of, and if necessary effect control of this situation, wind sheer data from storm events must be collected. This wind sheer data would give a value for the shortest distance over which winds blowing at high speeds and winds blowing at low speeds could be simultaneously measured. (Wind sheer) This distance, if it should be small enough, (e.g. 30 feet) would be used as a guide. The building's entire calculated minimum vent area (as per Equation C) would have to be installed every 30 feet. If the distance was 500 yards then this adjustment would not be necessary as very few buildings are that long. (The distance value will depend upon the wind event that the building is being rated for, tornadoes will tend to have a greater wind sheer potential)(See fig 11)

paragraph27.

PARAMETER 2

It is also important that the profile of a given building be studied. The calculated area of venting required to keep the roof on, must be the area of venting exposed to high winds, regardless of their direction. (The positive effects on air evacuation of the pressure drop on the turbulent drag / leeward side of the building are discounted, they represent a safety margin).

The design of the above building means that the minimum possible roof surface area exposed to high wind is ½ of the total roof surface area. The calculated minimum surface area of venting required, must therefore be present on both sides of the roof.

It is apparent that the house profile must be studied, and the direction from which the wind blows over the least roof surface area ascertained. That roof surface area must have the calculated necessary area of venting to prevent roof loss. The same formula must be

applied to every wind direction and related windward roof surface area exposed (see fig13).

paragraph28.

PARAMETER 3

As a general guideline, it is better to have the minimum required venting area divided into several vents and spread evenly across the roof. (See fig 12)(Studies have been done, which map the intensity of pressure drop on different sections of a roof. Using this data, zones of highest-pressure drop could be given a proportionately higher concentration of vents. The report that I viewed however, involved tests done on a horizontal shed like roof and data from all common roof angles would have to be generated and analyzed before optimal vent concentration patterns could be designated.)